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Abstract

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From genome to phenotype: Modeling the interaction of physical and chemical signals in plant meristems

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To develop a predictive theory of development – how to get from genome to phenotype – my laboratory and others have been developing Computational Morphodynamics — the use of live imaging and computational models to capture and model the causal mechanisms of development at the cellular and tissue level. By live image analysis of shoot apical meristems, the stem cell populations in flowering plants for all above-ground tissues, we have found that chemical and physical signals interact to lead to pattern. Chemical signals in the shoot meristem include secretion of signaling peptides that are ligands for receptor kinases, diffusion of small molecules such as cytokinins, and regulated transport of other small molecules, auxins. Physical signals are less understood, but recent work makes it clear that meristem cells reorganize their cytoskeletons parallel to maximal stress, and that stress-aligned microtubules determine the anisotropic properties of cell walls – which in turn alter stress patterns. Both processes are important for morphogenesis at the shoot apex and have multiple feedback loops, thus leading to the need for explicit mathematical models. The processes interact in producing the phyllotactic pattern, the spiral pattern of leaves and flowers around the stem. Computational models of phyllotaxis and primordial growth at the shoot apex show how local interactions of cells lead to complex global patterns, and have led to predictive and tested models for several aspects of plant growth and development.

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